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Design and Simulation of RFID Tag for Container-Grown Seedlings System

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Abstract

In precision agriculture (PA), the differences of the agriculture related parameters such as temperature, humidity, soil moisture among different fields are considered and analyzed to precisely utilize water, pesticides, fertilizer, seeds, etc. in fields. Hence, it becomes possible to increase the profit, reduce waste and maintain quality products. This paper suggests a framework for RFID sensor network in view of PA, especially, associated with Container-grown seedlings(CGS), and presents the analysis and simulation by using Ultra High Frequency (UHF) RFID tag system. The simulation is divided into the transmitter and receiver part using Matlab/Simulink. The architecture of the model is flexible to achieve different modulation and encoding types. Finally, some results of the simulation are presents.

Keywords: *Container-grown seedlings, PA, RFID, UHF*

1. INTRODUCTION

Precision agriculture (PA) is mainly used in developing countries. In PA, the differences of the agriculture related parameters such as temperature, humidity, soil moisture, rainfall among different fields are considered and analyzed to efficiently (precisely) utilize water, pesticides, fertilizer, seeds, etc. in fields. Hence, it becomes possible to increase the profit, reduce waste and maintain quality products. Though, GIS and GPS are used for PA, they are costly. RFID sensor networks provide a low-cost technological solution for PA, for instance, in field crop management [1, 2] where sensor networks monitor crop conditions/growth for a longer period of time, make decision remotely and evaluate the potential of new crops. Moreover, using the data collected by RFID sensors, it is possible to create a database or knowledge base of in-fields crops [3, 4].

In recent years, several efforts to restore the warm-temperate forests have been initiated by national and local governments. In particular, container-grown seedlings are very useful to attain the healthy seedling production and to find an appropriate regeneration model for the successful restoration of the warm-temperate forests. Container-grown seedlings have been developed to produce the fast growing and high adaptive seedlings that have the high field survival rates. However, information technology is not currently being used in the container-grown seedling system. A usable, adaptive and sustainable sensor-based monitoring system is required for high quality seedlings of each tree species.

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UHF RFID technology has drawn a swirl attention because of its wide applications in many fields recently, such as passport, food safety, and production tracing, etc. [5]. As a technology utilizing wireless radio waves to transmit, identify, trace and confirm numerous objects, RFID is applied to identify articles or people fast, accurately, and inexpensively [6]. Based on power source, RFID would be classified into two types-active and passive. The passive tag is powered by Radio Frequency (RF) wave emitted from a reader, while the active tag has to work with a embed battery [7, 8]. It is crucial to design low power circuits for the tag, especially a low power digital baseband, for that the operating distance of the passive tag is highly dependent on the power consumption.

In this paper, we present a framework especially, the topology and routing protocol for the container-grown seedling system based on Common-sense Net (CNS) project, which provides a solution by using autonomous sensor network and apprenticeship to learn the system. CNS uses a participatory iterative design and implements a technology-based solution in a very first iteration, uses and evaluates it in the local community/culture and performs improvements or redesign in the next iteration based on the feedback or output of the current iteration. Next, we present the analysis and simulation using Ultra High Frequency (UHF) RFID tag system. The simulation is divided into the transmitter and receiver part using Matlab/Simulink. The architecture of the model is flexible to achieve different modulation and encoding types.

2. TECHNICAL FRAMEWORKS

A zone-based topology suffers from network coverage problem and reliability. In [3], they suggest a dynamic zone-based topology for VESEL project. Initially, nodes are distributed to the zones based on the condition that each node remains within the range of the nodes of at least two zones. This overcomes the problem of node isolation. Then, each node identifies their neighboring nodes by broadcasting node/zone ID that is assigned by the gateway/coordinator nodes. Each zone node elects' nodes in the neighboring zones to which they can connect with a minimum transceiver power. This generates several connected graphs, and the graph that requires minimum transmission power is selected for routing. The topology of sensor-based irrigation system described in [9] is a tree structure (single sink, multi-source), where the only base station (BS) is at the root. However, this topology is not reliable since there is only one path from each node to the BS. Any link or node failure can make other nodes unreachable to the BS.

The VESEL project has a delay tolerant multi-sink architecture and back-link/storage aware routing protocol for. Multiple sinks provide more storage capabilities and distributed data collection. Data are aggregated to several sink nodes. Sinks are located at the edge of a field and thus, supports automatic data logging when some hand-held community devices such as PDA pass by the sinks. In back-link/storage aware routing protocol, sinks and other nodes broadcast available memory/storage capacity. If the back link is available and of good quality, multi-hop routing protocol to find the next hop is used. Otherwise, if the storage capacity of sink is not enough, data will be stored locally or in neighboring nodes. In this way, routing balances or optimizes memory usage.

For routing in the tree topology of sensor-based PA systems [10], each node has an ID and neighboring node information table. Each node uses local routing, that is, broadcasts only data/packets to the neighbors. The BS initiates routing by sending a message of type 1. Whenever, a node receives this message it keeps the neighbor information into its routing table. Each node clears it routing table after T cycles, when a new round will be initiated. Whenever a node wants to join the network or the routing information table of a node is empty, the node sends a joining request message of type 2. The nodes, which are in the network and receive the type 2 message, reply with a type 3 message. The original node then compares the hop count of the nodes that sent the message of type 3. If the hop count of that node is smaller than that of the original node, the node that replied the type 3 message can be a potential parent of the original node. The type 4 message from a child to parent is sent to know whether the parent is still alive. The parent replies by sending a type 5 message and the child updates its local routing table for its parent. If a child does not receive the type 5 message before a timer expires, the child assumes that the parent is dead and so, re-selects a parent. Re-selecting a parent may slow down the network. Moreover, any link failure may cause the BS unreachable.

Common Sense Net(CSN) uses a centralized data collection subsystem, where each node sends the collected data to the central sever through BS. As the nodes are not mobile and topology does not change frequently, CSN uses tree construction multi-hop routing algorithm. In sensing subsystem, Mica2 motes (includes temperature, humidity, ambient light sensors) are used. Mica2 nodes have low power consumptions and highest radio range among the current sensor technology. CSN uses multi-hop routing protocol that is embedded in the Tiny OS software system. For saving energy, transmission rate is maintained lower than the sampling rate. For connecting different subsystems, CSN uses IEEE 802.11 (Wi-Fi) wireless links. A Java based application is used to log data and metadata in the database of sensor network. As there was no GSM/GPRS connectivity in rural areas when the CSN project was first implemented, expensive and energy inefficient Wi-Fi links/bridges were used. However, due to the recent improvement/connectivity of GPRS technology, it is being used in the CSN as a bridge to aggregate and transmit data to the central server.

3. DESIGN OF FRAMEWORKS AND SIMULATION ARCHITECTURES

The framework, as is illustrated in Fig Figure 1 uses RFID sensor networks [11] by integrating sensors in container-grown seedling field with other wireless devices such as PDA, smart phones. Data collected from sensors are transmitted to central server through different wireless devices and networks (e.g., Wi-Fi, GPRS). The central server has different components for data storage, processing and notifications such as database management systems, alarm systems. It also integrates an efficient crop model/decision support system that is suitable for agriculture in developing regions as well as building a timely and cost-effective IT infrastructure through IT apprenticeship as an iterative process.

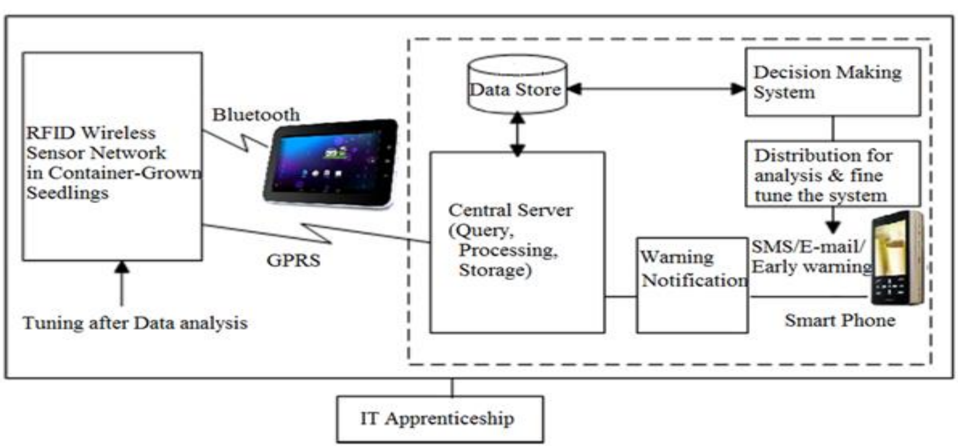

Figure 1. RFID sensor-based Container-grown seedling system

Besides, the framework focusses on designing an energy efficient and reliable zone-based topology and routing protocol for agricultural sensor network where multiple base stations (BS) or gateway node can be placed outside of the network area so that sensors can communicate with the nearest BS to reduce energy consumptions. Moreover, a few more alternative sensors nodes can be distributed to zones that are closest to BS than those of the farthest zones from BS. An alternate becomes an active node after a fixed number of data sensing operations either if the current active node fails or is at energy critical condition. Efficient shortest path establishment to achieve energy efficiency, providing fault tolerance to achieve reliability of the framework should also be considered.

The RFID system contains two parts, Reader and Tag [12]. The different transmission frequencies are classified into the four basic ranges, LF, HF, UHF and microwave (e.g. *2.4GHz*). For LF and HF RFID, the read range is usually less than *60cm*. For microwave RFID, because of the sensitivity to the environment, the maxim reader range is about *1m*. For UHF RFID, the read range can generally reach to *5m*. Also, the RFID system can be classified into active RFID (Tag with battery) and passive RFID (Tag without battery). We only discuss the passive UHF RFID system. In passive RFID, reader should send out electromagnetic waves first to wake-up tag, and then transmit the modulated wave to command tag.

A passive tag absorbs power from the field created by the reader and uses it to power the microchip's circuits. Then Reader transmits continuous wave (CW), while tag backscatters the information. There are many protocols about UHF RFID, in this paper, the simulation is mainly based on EPC class 1 and EPC class 1 generation 2 UHF RFID (abbreviate as Gen 2) protocols.

The proposed tag system, as shown in Figure 2, consists of antenna, analog section, Multi-time programming, and digital baseband.

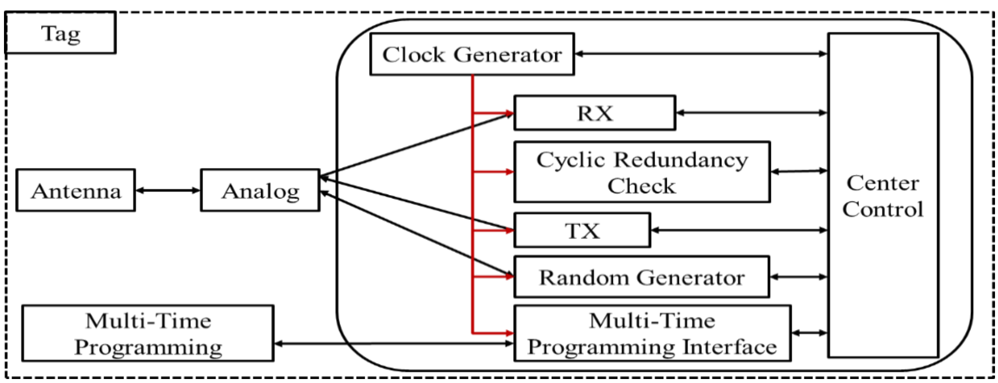

Figure 2. Architecture of the tag system

Antenna receives signal from reader, then the signal would be demodulated by analog front end. With regard to the digital baseband, our design implementation has 7 modules: Center control, Clock generator, TX, RX, CRC (Cyclic Redundancy Check), random generator, multi-time programming interface, shown in Figure 2.

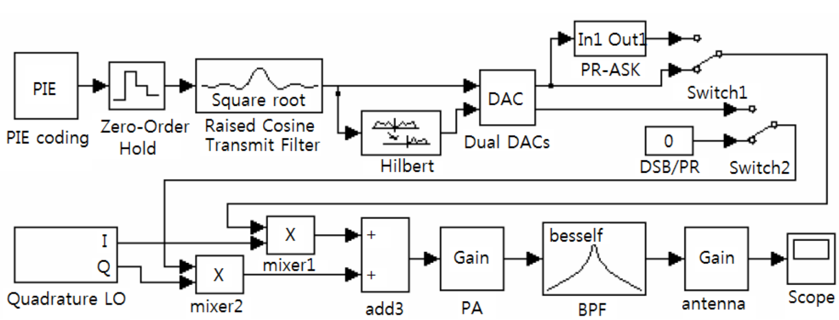

Figure 3. Transmitter Simulation Architecture

Figure 3 represents the transmitter architecture of UHF RFID by Matlab/Simulink. In Class 1 protocol, the reader shall communicate with the tag by Amplitude Shift Keying (ASK) modulation, and the modulation depth is from 30% to 100%. In Gen 2 protocol, the reader shall use double-sideband amplitude shift keying (DSB-ASK), single-sideband amplitude shift keying (SSB-ASK) or phase-reversal amplitude shift keying (PR-ASK), and the modulation depth is from 80% to 100%. It can implement all these modulation types. Assuming that the input signal is $f(t)$, which is the binary data passed through raised cosine filter, DAC and filter etc. Local oscillation uses dual orthogonal signals to generate the SSB-ASK modulated wave, denote as $\sin(\omega t)$ (I branch) and $\cos(\omega t)$ (Q branch). For other modulation types, it should adjust the input of Q-branch to 0. The modulation depth is only depending on the proportion of AC offset and DC offset. PR-ASK modulation inverts the phase at every symbol binary.

The architecture of reader receiver in simulation using Matlab/Simulink is shows in Figure 4. In Class 1 protocol, tags reply to reader commands with backscatter modulation with the encode form, where two transitions are observed for a binary zero and four transitions are observed for a binary one during one-bit cell.

And the data rate of return link is 140.35Kbps (in north america) or 30Kbps (in europe). In Gen 2 protocol, tags shall encode the backscattered data as either FM0 baseband or miller modulation of a subcarrier at the data rate. The reader selects the encoding type. FM0 inverts the phase at every symbol boundary; a data-0 has an additional mid-symbol phase inversion.

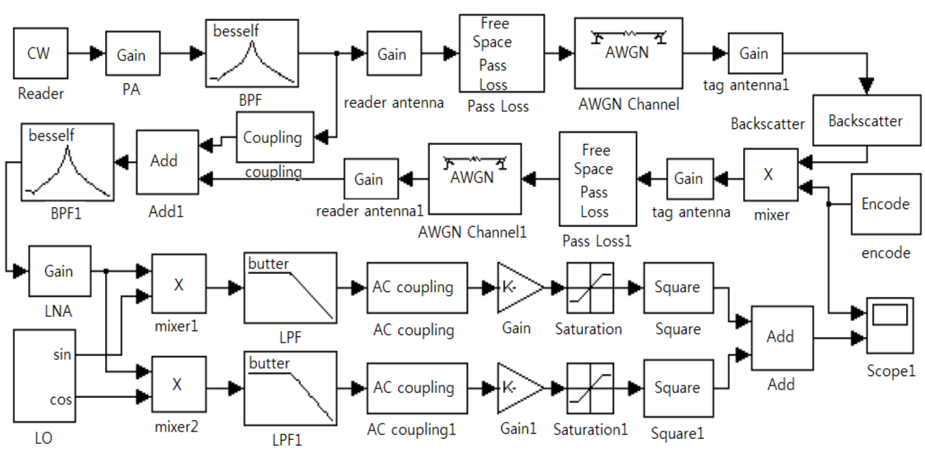

Figure 4. Receiver Simulation Architecture

The formula of the free space pass loss is $Ls(dB)$ = 32.45+20log$_2$ f (MHz)+ 20 log$_2 d(Km)$, where f is the carrier frequency, d is the distance between Reader and Tag. In the return link, Tag communicates with the Reader by backscatter modulation. During backscatter Reader transmits an un-modulated continuous wave (CW) signal, then, Tag modulates its reflection of the CW signal. In Class 1 protocol, Tag modulates the amplitude of the carrier (ASK). In Gen 2 protocol, Tag modulates the amplitude and/or phase of the carrier (ASK and/or PSK). Modulation of the backscattered wave is achieved by changing the tag IC's input impedance between two different states $Z_1 = R_1 + jX_1$ and $Z_2 = R_2 + jX_2$. For ASK, it is achieved by a change in the real part of the impedance and of the reflection coefficient. And PSK is achieved by changing the imaginary part of the input impedance and of the reflection coefficient. In this paper, we will only discuss the ASK case.

In backscatter, the reflection coefficient is defined as $\rho_{12} = (Z_{12} - Z_a^*)/(Z_{12}+Z_a)$, where $Z_a = R_a + jX_a$ is the input impendence of antenna, and $Z_a^* = R_a + jX_a$ is the complex conjugate of the antenna impedance. If the antenna and IC are optimum matched, then $Z_{12} = Z_a$. Assuming the available power received by Tag is P and the two states of IC are active an equal amount of time, then the reflect power is the same as $P_b = P(\rho_1 - \rho_2)^2/(4L_a)$, where L_a is is antenna loss factor. If antenna and IC is optimum matched in one state, $\rho_1 = 0$, and totally un-matched in the other state, $\rho_2 = 1$, then reflect power is 25% of the available received power.

As this analysis, the Tag reflection power is much weaker than the Reader transmitting power, and Reader transmits CW signal and receives the backscatter signal at the same time. So the key problem of Reader is the receiving. The method to solve this is using the Zero-IF receiver, namely the frequency of local oscillator is the same as carrier frequency. Because Reader transmits CW signal and receives the backscatter signal simultaneously, so there may be part of the CW signal leak into the receive circuit, denotes as $A\sin(\omega t)$. For Tag backscatter signal, Tag modulates its data on this CW signal, and it may have a random phase, so it denotes as $f(t)\sin(\omega t+\theta)$. To solve the phase problem, the receive circuit uses dual orthogonal local oscillation signals such as $2B\sin(\omega t)$ and $2B\cos(\omega t)$.

4. RESULT

Several simulation results are presented by changing the modulation and encoding types. Figure 5 shows the modulation results using PIE encoding according to the class 1 protocol. And the modulation depth is 100% (above) and 30% (below). Figure 6 shows the modulation results using PIE encoding according to the Gen 2 protocol using DSB-ASK modulation. And the modulation depth is 100% (above) and 80% (below). Figure 7 shows the modulation results using PIE encoding according to the Gen 2 protocol using SSB-ASK modulation.

And the modulation depth is 100% (above) and 80% (below). Figure 8 shows the modulation results using PIE encoding according to the Gen 2 protocol using PR-ASK modulation. And the modulation depth is 100%. Figure 9 shows the detail between two symbols, the phase reversal between symbols can be seen clearly.

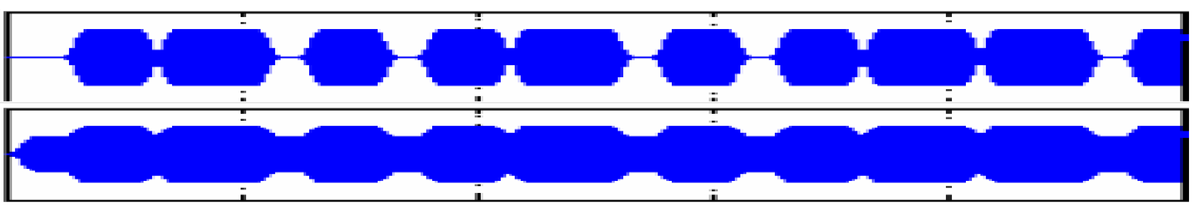

Figure 5. Class 1 PIE Modulation

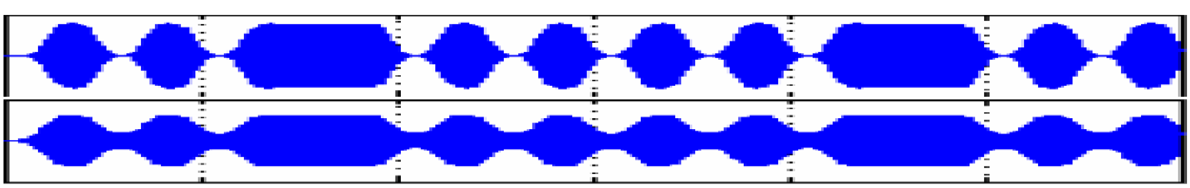

Figure 6. Gen 2 DSB modulation

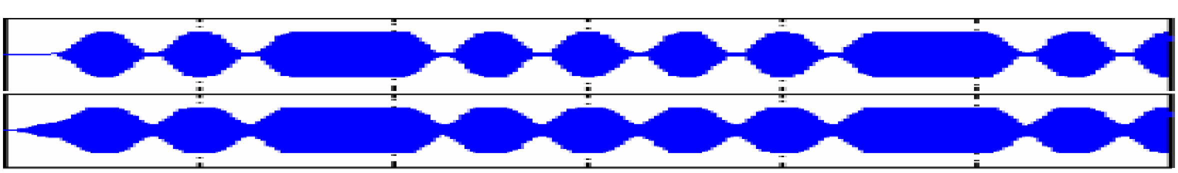

Figure 7. Gen 2 SSB modulation

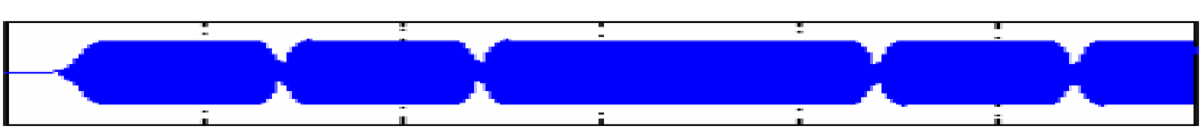

Figure 8. Gen 2 PIE coding PR-ASK

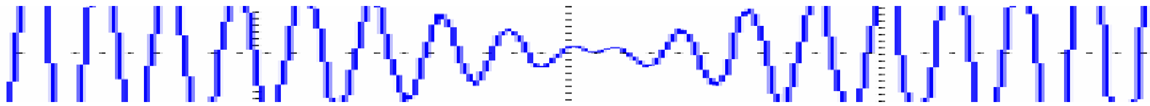

Figure 9. Phase reversal between symbols modulation

The transmit power is designed to be 36dBm (EIRP), the gain of antenna is set to be 6dB. Figure 10 denotes the demodulated signal. And the distance between reader and tag is 1m (above) and 5m (below).

The simulation results below are the compare of tag encoding data and reader demodulated data in different encoding types, tag encoding sequence are all “0110010011” in three pictures. The distance between reader and Tag is 1m. And the received signal is rectified by amplifier and limiter.

Figure 11 denotes the demodulation results using the encoding according to Class 1 protocol. The above signal is Tag baseband data, and the below signal is the Reader demodulated signal.

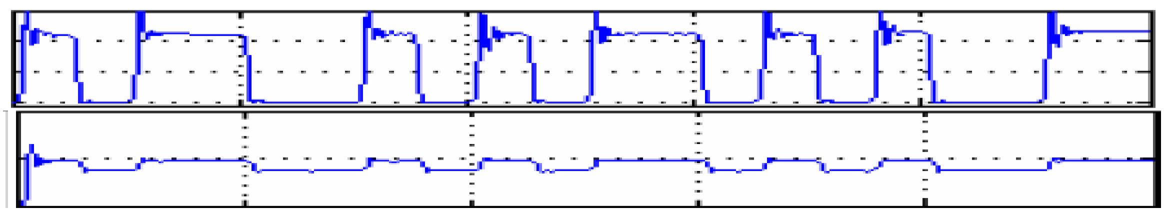

Figure 10. Receive signal

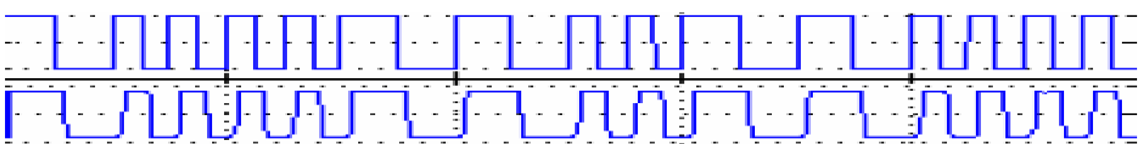

Figure 11. Class 1 encoding demodulation

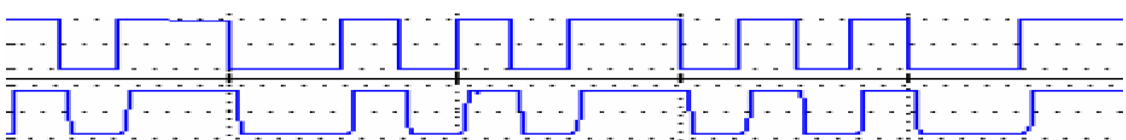

Figure 12. Gen 2 FM0 encoding demodulation

Figure 12 represents the demodulation results using FM0 encoding according to Gen 2 protocol. The above signal is tag baseband data, and the below signal is the reader demodulated signal. Figure 13 shows the demodulation results using miller subcarrier according to Gen 2 protocol, where the value of M is 2. The above signal is tag baseband data, and the below signal is the reader demodulated signal.

5. CONCLUSION

In this study, we propose a framework for RFID (Radio Frequency Identification) sensor network from the perspective of precision agriculture (PA) related to container-grown seedlings, and present analysis and simulation of two protocols using UHF (Ultra High Frequency) RFID. did Different types of encoding and modulation have been used in tag systems and simulations. The architecture of the receiver is designed to solve the CW leakage problem and the random phase problem. The tag backscatter information can be fully demodulated from the simulation results of the receiver.

Therefore, this paper conducted several simulations by changing the modulation and encoding type, and confirmed the modulation result using PIE encoding according to the class 1 protocol. As a result, the modulation depth was 100% (top) and 30% (bottom). The modulation result using PIE encoding according to the Gen 2 protocol using DSB-ASK modulation showed that the modulation depth was 100% (top) and 80% (bottom). As a result of using PIE encoding according to the Gen 2 protocol using SSB-ASK modulation, the modulation depth was 100% (top) and 80% (bottom). The modulation result using PIE encoding according to the Gen 2 protocol using PR-ASK modulation showed that the modulation depth was 100%. It also shows the detail between the two symbols, and the phase inversion between the symbols can be clearly seen.

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